Aircraft Electric/Hybrid-Electric Power & Propulsion Workshop Perspective of the V/STOL Aircraft Systems Tech Committee

Workshop to be held July 28th, 2016 at the Hilton Salt Lake City Center in Salt Lake City, Utah

Schedule

0700 – 0800	Check-in and Continental Breakfast
0800 – 0830	Introduction and welcome by AIAA
0830 – 0930	Speakers from adjacent research Large Scale Batteries, by R. Chamberlain (invited) and Extreme Electric Machines by Kiruba Haran
0930 – 1030	Panel: Visions of the Future Featuring John Nairus (AFRL), Cheryl Bowman (NASA) and Dr. Babu Chalamala (Sandia National Lab, invited)
1030 – 1100	Coffee Break
1100 – 1205	Panel: Activities from AIAA Committees Featuring Ilan Kroo (Aircraft Design TC, invited), **Craig Hange (V/STOL Aircraft Systems TC, invited)**, Andrew Gibson (Green Engineering PC, invited), John Nairus (Energy Optimized Aircraft and Equipment Systems PC)
1205 – 1305	Lunch
1300 – 1515	Breakout session introduction and rotation through discussion breakout sessions (technology, systems integration, standards, certification, and role of AIAA
1515 – 1545	Coffee Break
1545 – 1630	Reports from breakout sessions
1630 – 1700	Wrap- Up and Next Steps
1700 – 1715	Closing Comments by AIAA

Vertical Short Take-Off Landing (V/STOL) Aircraft Systems Technical Committee

- We are advocates for the use of powered-lift technology to provide enhanced capability to new aircraft concepts to promote improvements to the Air Transportation System
  - Military – Includes austere basing where access to airfields may be denied. Permits dispersion of assets for protection from attack, deployment of assets closer to the front
  - Civilian – Increasing throughput by opening up unused or underutilized airports and runways. Access to austere areas in the event of emergency or catastrophe
  - UAV – Permit take-off and landing at or near areas of operational interest. Permit low-speed / hovering operations in certain scenarios (Power line inspection for example)
  - Rotorcraft and Helicopter – Access to austere locations, thin haul routes, urban commuting, rescue and medical evacuation
  - Personal Air Vehicle – True “point-to-point” service

Technical & Operational Issues Endemic to V/STOL

- Powered – Lift, Using thrust to provide lift when aerodynamics are insufficient due to low-speed (low dynamic pressure)
  - Maintaining lift greater than weight
  - Sufficient control power and authority to maintain flight path
- Flow Field Effects
  - In-ground-effect induced forces caused by thrust entrainment
  - Thrust impingement and recirculation – Hot gases and their influence on aircraft and environment
- Noise and Acoustics – On aircraft, near field, and far field

Technical & Operational Issues Endemic to V/STOL

- Aircraft balance issues
  - Keeping the thrust at the center-of-gravity (CG)
  - Ability to provide control moments about the CG
- Internal plumbing and routing
  - Moving air to other areas of the airframe to provide thrust where it will maintain balance. Takes up important volume in the aircraft.
  - Vectoring nozzles or vectoring engines. Both introduce complexity, weight, and cost.
  - Lift augmentation – Using favorable interactions of the flow to create additional lift – Upper surface blowing, circulation control, ejector nozzles
- Mission integration issues – What other requirements are contrary to V/STOL performance e.g. – Supersonic performance for F-35B

Technical & Operational Issues Endemic to V/STOL

- One engine inoperative (OEI) for 2 or more engines
  - Loss in thrust that is countering drag and providing lift
  - Inability to provide restoring moments
  - The promise of a slower take-off and landing should improve safety, not diminish it
- Mechanical solutions to OEI or critical engine inoperative (CEI) are complex, hard to maintain, and expensive
- A wide operating range of airflow momentum requirements to generate the most efficient thrust beg for the use of true variable bypass ratio
  - US / UK, CALF, JAST, X-32, X-35, F-35 all incorporate variable bypass in one form or another

Addressing Technical & Operational Issues Endemic to V/STOL

- Distributed propulsion is a potential revolutionary answer
  - More propulsors means smaller impact of OEI (ref 2004 study)
  - Smaller propulsors can be integrated on other locations on the aircraft improving effectiveness, freeing up volume, and reducing induced jet effects
  - On / off “binary” throttle settings may be viable (Engine runs “on-design” only)
- However….
  - Mechanical complexity associated with ‘n’ turbo-machinery based units is increased dramatically
  - Propulsion sub-systems also went from 2 to ‘n’. There is very little benefit from being used on smaller thrust engines
  - Economies of scale works against DP in turbomachinery efficiency, weight, and manufacturability (Bypass ratio becomes smaller)

Distributed Propulsion

- RSCA Studies 2004 – 2005, EMAX Concept used 22 engines

Addressing Technical & Operational Issues Endemic to V/STOL

- Distributed Electric / Hybrid Electric Propulsion is a potentially a better answer for V/STOL operations
  - Gas generator performance is potentially decoupled from fan performance
  - The number of potential systems architectures increases, but this permits better mission tailoring

Addressing Technical & Operational Issues Endemic to V/STOL

- Transfer of power accomplished via electricity through (relatively) small wiring, not hot air pipes or mechanical rotating shafts
- Power transfer not confined to certain areas due to volume constraints (e.g. Piping fan air across the fuselage is impractical)
- Hot air energy is created and expended in the turboshaft only. There is very little hot air exiting the aircraft
- Fans are used for all thrust
- Fans can be dissimilar in size and momentum
- Does not need to be turboshaft powered. Could be diesel
- Very high bypass ratio. True variable-bypass ratio capability
- An overspeed capability, and a battery augmentation capability
- Electric is really the only way to go for small UAV

Addressing Technical & Operational Issues Endemic to V/STOL

- Issues and concerns
  - Large amounts of sensors, actuators, and data transfer required
  - Integrated airframe & propulsion is required and is complex
  - Cooling systems for embedded components and electrical inefficiencies distributed in the airframe. Active cooling potentially needed for low-speed or hover.
  - Cryogenic and superconducting may be needed to get better efficiencies
  - Existing generator / motor industry not accustomed to working to aircraft power-to-weight goals

Schematic of Distributed Turbo-Electric STOL Aircraft